Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application.

1. (Currently amended) A method ~~for reducing required coherence time for a quantum computation,~~ comprising:

~~constructing~~ (A) obtaining a first series of operations for implementation on a quantum computing device comprising a plurality of qubits, wherein

(i) quantum interaction between qubits in the plurality of qubits is limited to nearest-neighbor coupling;

(ii) said first series of operations designates a plurality of operations and, for each respective operation in said plurality of operations, a time step in which said respective operation is implemented on the quantum computing device; and

(iii) said first series of operations collectively implements a quantum calculation ~~on qubits that perform the quantum computation~~; and

~~constructing~~ (B) deriving a second series of operations from the first series of operations by changing an execution order of a first operation and a second operation in said plurality of operations, wherein

(i) the second series of operations is for implementing the quantum calculation on the quantum computing device;

(ii) the first operation and the second operation commute; and

(iii) ~~the commuting operations to reduce the~~ said deriving causes a time required for ~~a~~ the quantum computing device to complete the second series of operations to be less than a time required for the quantum computing device to complete the first series of operations.

2. (Currently amended) The method of claim 1, wherein the deriving ~~constructing the second series of operations from the first series of operations~~ comprises changing the execution order of the first operation and the second operation ~~commuting operations in the first series~~ so that ~~two or more operations~~ the first operation and the second operation are performed in the same time step on the quantum computing device ~~simultaneously in the second series~~.

3. (Currently amended) The method of claim 2, wherein the first series of operations

includes a swap operation that changes a first qubit and a second qubit in the quantum computing device from having respectively a first state and a second state to having respectively the second state and the first state.

4. (Currently amended) The method of claim 3, wherein:

changing the execution order of the first operation and the second operation ~~commuting operations~~ eliminates a need for the swap operation in order to compute said quantum calculation; and

the deriving ~~constructing the second series~~ further comprises omitting the swap operation from the first series of operations in order to form the second series of operations ~~so that execution of the second series of operations performs the quantum calculation faster than executing the first series of operation~~.

5. (Currently amended) The method of claim 1, wherein

the first series of operations includes a swap operation that changes a first qubit and a second qubit in the quantum computing device from having respectively a first state and a second state to having respectively the second state and the first state; ~~and~~

changing the execution order of the first operation and the second operation ~~commuting operations in the first series~~ eliminates a need for the swap operation in order to compute said quantum calculation; and

the deriving ~~constructing the second series~~ further comprises omitting the swap operation from the first series of operations in order to form the second series of operations ~~so that execution of the second series of operations performs the quantum calculation faster than executing the first series of operation~~.

6. (Currently amended) A method ~~for performing a swap operation in a quantum computing device, the method~~ comprising:

performing a plurality of operations selected from a ~~sequence~~ series of operations~~;~~ ~~and~~ on a quantum computing device, wherein

the quantum computing device comprises a plurality of qubits;

the plurality of operations collectively implements a swap operation between two neighboring qubits in the plurality of qubits;

a first operation and a second operation in the plurality of operations commute;

the plurality of operations includes a third operation that does not commute with either the first operation or the second operation;

the first operation and the second operation are each implemented before or after the third operation in the plurality of operations; and

the first operation and the second operation are simultaneously executed by said performing on different qubits in the plurality of qubits.

~~simultaneously performing two of the operations that commute~~.

7. (Currently amended) The method of claim 6, wherein said performing ~~the sequence of operations~~ comprises:

simultaneously performing a first operation $Z_r(\pi/2)$ on a qubit r and a second operation $Z_s(\pi/2)$ on a qubit s in said plurality of qubits;

sequentially performing a third operation $X_s(\pi/2)$ on the qubit s, a fourth operation $Z_s(\pi/2)$ on the qubit s, and a fifth operation $CP_{rs}(\pi/2)$ on the qubits r and s;

simultaneously performing a sixth operation $X_s(\pi/2)$ on the qubit s and a seventh operation $X_r(\pi/2)$ on the qubit r;

sequentially performing an eighth operation $Z_r(\pi/2)$ on the qubit r, and a ninth operation $CP_{rs}(\pi/2)$ on the qubits r and s;

simultaneously performing a tenth operation $X_r(\pi/2)$ on a qubit r and an eleventh operation $Z_s(\pi/2)$ on a qubit s; and

sequentially performing a twelfth operation $X_s(\pi/2)$ on the qubit s, a thirteenth operation $Z_s(\pi/2)$ on the qubit s, a fourteenth operation $CP_{rs}(\pi/2)$ on the qubits r and s, and a ~~sixteenth~~ fifteenth operation ~~$X_s(\pi/2)$~~ $X_s(3\pi/2)$ on the qubit s.

8. (Currently amended) The method of claim 7, wherein the third, sixth, seventh, tenth, twelfth, and ~~sixteenth~~ fifteenth operations act on ~~the two~~ a first state and a second state ~~states~~ of the respective qubits according to the ~~following~~ equation:

$$X(\theta) = e^{\frac{-i\sigma_x\theta}{2}}.$$

9. (Currently amended) The method of claim 7, wherein the first, second, fourth, eighth, eleventh, and thirteenth operations act on a first state and a second state ~~the two states~~ of the respective qubits according to the ~~following~~ equation:

$$Z(\phi) = e^{\frac{-i\sigma_z\phi}{2}}.$$

10. (Currently amended) The method of claim 7 ~~6~~, wherein the fifth, ninth, and fourteenth operations act on ~~the four combined states~~ a first state and a second state of the ~~qubits~~ r and a first state and a second state of the qubit s according to the ~~following~~ equation:

$$\cancel{CP(\varsigma) = e^{\frac{-i\sigma_z \otimes \sigma_Z \varsigma}{2}}}$$

$$\underline{CP(\zeta) = e^{\frac{-i\sigma_z \otimes \sigma_Z \zeta}{2}}}.$$

11. (New) The method of claim 1, wherein the plurality of qubits consists of a one-dimensional array of qubits.

12. (New) The method of claim 6, wherein the plurality of qubits consists of a one-dimensional array of qubits.

13. (New) The method of claim 1, wherein a qubit in the plurality of qubits comprises a Josephson junction between a superconducting bank and superconducting mesoscopic island.

14. (New) The method of claim 13 wherein the superconducting bank, the superconducting mesoscopic island, or both the superconducting bank and the mesoscopic island are made of a high-Tc superconductor.

15. (New) The method of claim 6, wherein a qubit in the plurality of qubits comprises a Josephson junction between a superconducting bank and a superconducting mesoscopic island.

16. (New) The method of claim 15 wherein the superconducting bank, the superconducting mesoscopic island, or both the superconducting bank and the mesoscopic island is made of a high-Tc superconductor.

17. (New) The method of claim 1 wherein the quantum calculation is a quantum Fourier transform.

18. (New) The method of claim 17 wherein the plurality of qubits comprises n qubits and the quantum Fourier transform is calculated on the quantum computing device in about O(n) time steps.

19. (New) The method of claim 1, the method further comprising:

executing said second series of operations on said quantum computing device thereby computing said quantum calculation.

20. (New) The method of claim 6, wherein said swap operation between the two neighboring qubits swaps a first quantum state initially stored in a first of the two neighboring qubits and a second quantum state initially stored in a second of the two neighboring qubits.

21. (New) The method of claim 1 wherein

said first series of operations comprises a plurality of swap operations; and

said deriving results in an absence of one or more of said swap operations in said plurality of swap operations in said second series of operations.

22. (New) A method comprising:

presenting a first series of operations that collectively implement a calculation on a quantum computing device, the quantum computing device comprising a linear array of qubits wherein

all qubit-qubit interaction in said quantum computing device is limited to nearest neighbor coupling; and

a portion of said calculation requires two neighboring qubits in said plurality of qubits having indices i and j, where $|j - i|$ is greater than three, to couple; and

rearranging an execution order of swap operations in a plurality of swap operations in said first series of operations thereby deriving a second series of operations for implementing said calculation, wherein

said second series of operations includes a first operation that simultaneously swaps a state stored on qubit j with a state stored on qubit $(j - 1)$, and a second operation that simultaneously swaps a state stored on

qubit i with a state stored on qubit (i + 1) in said plurality of qubits, wherein

qubits j and (j-1) are adjacent to each other in said linear array; and

qubits i and (i+1) are adjacent to each other in said linear array.

23. (New) The method of claim 6, wherein said plurality of operations selected from the series of operations does not include one or more redundant gates in said series of operations.

24. (New) The method of claim 23, wherein the series of operations includes a subset of operations that occur sequentially as:

a first operation $Z_r(\pi/2)$ on a qubit r in said plurality of qubits;

a second operation $Z_s(\pi/2)$ on a qubit s in said plurality of qubits;

a third operation $CP_{rs}(\pi/2)$ on the qubits r and s; and

a fourth operation $X_r(3\pi/2)$ on the qubit r;

wherein the operation $CP_{rs}(\pi/2)$ and the operation $Z_r(\pi/2)$ are each redundant gates and wherein one or both of the operation $CP_{rs}(\pi/2)$ and the operation $Z_r(\pi/2)$ is not included in said plurality of operations.

25. (New) The method of claim 23, wherein the series of operations includes a subset of operations that occur sequentially as:

a first operation $Z_r(\pi/2)$ on a qubit r in said plurality of qubits;

a second operation $Z_s(\pi/2)$ on a qubit s in said plurality of qubits; and

a third operation $CP_{rs}(\pi/2)$ on the qubits r and s;

wherein the operation $CP_{rs}(\pi/2)$ is a redundant gate that is not included in said plurality of operations.